BENTHIC POPULATION DISTRIBUTIONS IN RED ROCK RESERVOIR, IOWA SUMMER 1972

An abstract of a Thesis by
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The problem. To determine the distribution of benthic invertebrates in Red Rock Reservoir and to relate this distribution to the physiochemical characteristics of the substrate and bottom meter of water along with water retention time after three years of impoundment.

Procedure. Benthic samples were obtained at weekly intervals with a Ponar dredge from two transects of six stations each from June 9 to August 1, 1972. Bottom sediments were analyzed for organic content, pH and particle size. Bottom waters were analyzed for dissolved oxygen content, alkalinity and free carbon dioxide. Depth and temperature readings were recorded at each station.

Findings. During the study three major groups comprised the benthos. Of the total numbers collected during the study Oligochaeta comprised 52.4%, Chironomidae 44.8% and *Chaoborus* 2.8%. Total mean numbers collected ranged from 24 to 212 organisms/m^2. Thermal and chemical stratification of the bottom waters occurred temporarily.

Conclusions. The benthic standing crop in Red Rock Reservoir has increased since 1970 but the amount of biomass present and the mean density of organisms was below values obtained from other reservoirs. Low numbers of *Chaoborus* present were due to emergence patterns. Factors which appeared to influence benthic population distributions include substrate organic content and particle size, low water retention time and presence of the old river channel.

Recommendations. Future studies should determine the exact species composition of the benthos and how life cycle patterns are related to benthic biomass production and distribution. The influence of fish predation and sedimentation and the loss of production via reservoir flowthrough should be investigated.

BENTHIC POPULATION DISTRIBUTIONS
IN RED ROCK RESERVOIR, IOWA
SUMMER 1972

A Thesis

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

An increasingly important component of our surface water resources is artificial water impoundments. Broadening of our knowledge of reservoir ecology is essential to proper design and management. Although there have been many investigations on older reservoirs in North America, earlier studies are limited. To understand fish production and yield phenomena, the sequence of biological events associated with formation of new impoundments must be studied. The benthic community represents an important link in this production pattern and a study of its development offers a potential source of insight into the dynamics of bottom fauna (Aggus, 1971; Hayne and Ball, 1956; Paterson and Fernando, 1970; Schmulbach and Sandholm, 1962).

The extent and nature of the benthic communities that develop in newly constructed habitats show differences resulting from a wide range of edaphic characteristics and biological factors (Neel, 1963; Paterson and Fernando, 1970). Some of these factors may operate directly in limiting certain species, whereas, in other instances complex interactions of factors are limiting (Reid, 1961).

In contrast to natural lakes, reservoirs vary in a number of physical details. The water level in reservoirs varies considerably compared with that of a natural lake. Where water in a natural lake leaves from the surface portions, reservoirs generally discharge water from deep water layers and experience extensive draw downs (Neel, 1963; Wright, 1967). With deep water withdrawal the effluent tends to deplete the reservoir of nutrients that would normally be deposited in a natural lake (Wright, 1967). Reservoirs inundate rich bottom lands and fertile topsoils on river slopes and normally begin their lives with high productivity potential (Neel, 1963). Large quantities of organic debris present in reservoir basins can effect an early eutrophic stage in reservoirs (Paterson and Fernando, 1970).

In studies of early development of bottom fauna in Barrier Reservoir, Nursall (1952) found low retention time to be important in controlling the kinds of organisms and in effecting oligotrophic conditions. Schmulbach and Sandholm (1962) related a retention time of 8 to 10 days to the small standing crop of bottom fauna in Lewis and Clark reservoir on the Missouri River. Similar studies by Cowell and Hudson (1967) showed significant losses of benthic invertebrates through turbines. Isom (1971) stated that subsurface movements of the water were accelerated by draw down, and these physical and chemical changes could result in loss of significant benthic faunal elements.

Water depth and fluctuation have been indicated in determining bottom fauna distribution (Cowell and Hudson, 1967; Grimas, 1961; Isom, 1971; McLachlan, 1970; Mrachek and Bachmann, 1967; Nursall, 1952; Schmulbach and Sandholm, 1962). Benthic forms whose numbers have been shown to be determined by depth include Oligochaeta, Chironomidae (Bardach, Morrill and Gambony, 1951; Clampitt, Waffle and Bovbjerg, 1960) and Chaoborus punctipennis (Say) (Craven and Brown, 1969; Hilsenhoff and Narf, 1968). Water level fluctuations have been shown to influence benthic population numbers in reservoirs in Alberta and Sweden (Fillion, 1967; Grimas, 1961). Migration in response to water-level fluctuations, water temperature and population density also influenced the distribution and abundance of benthic invertebrates (Cowell and Hudson, 1967).

As reservoir substrate becomes modified by siltation and decomposition of organic detritus, definite correlations have been made to the development of benthic communities (Aggus, 1971; Bardach et al., 1951; Johnson and Matheson, 1968; Paterson and Fernando, 1970). Smith (1969) showed Chironomidae populations were associated with large amounts of organic detritus related to previous algae blooms. In West Lake Okoboji, the substratum was important in the distribution of characteristic inhabitants (Oligochaeta and Chironomidae). Several genera of Chironomidae, yielding large numbers, preferred areas adjacent to a sand spit (Pseudochironomus) and in the silt substratum (Tendipes) (Clampitt et al., 1960). Cowell and Hudson (1967) found abundance of Hexagenia nymphs and chironomid larvae to be inversely related to the percent sand in the substrate. Similar inverse relationships were made to coarser sediments, however bottom vegetation produced higher populations.

Thomas (1970) observed that the population of bottom-associated organisms decreased from the headend to the downstream end of Wilson Reservoir. This was related to a decrease in the deposition of organic material in the downstream direction. Grimas (1961) and Johnson and Matheson (1968) found a higher abundance of bottom organisms in the vicinity of inflows.

Increasing water temperature was correlated with a rapid increase in benthic population densities (Paterson and Fernando, 1970). Hamilton (1971) indicated that dissolved oxygen and temperature of the bottom water were probably the primary factors limiting the distribution of individual benthic species. Oxygen concentration appeared to be a major regulatory factor for vertical migration of <u>Chaoborus</u> larvae (LaRow, 1970). Dorris (1958) found that bottom organisms, except tubificid worms, were controlled by reduction of dissolved oxygen, particularly during the summer. Low densities of benthic invertebrates were also correlated with reduced oxygen concentration at the mudwater interface in Lewis and Clark Lake, Lake Francis Case and in main-stream reservoirs in the Tennessee Valley (Cowell and Hudson, 1967; Isom, 1971).

In a study of fourteen Wisconsin Lakes abundance of Chironomidae was correlated to interactions of the pH of the mud, the pH of the water, organic matter in the mud and percentage of water in the mud. The occurrence of Chironomus plumosus (L.), Procladius larvae and Ostracoda was correlated with increased pH of the mud and negatively correlated with organic matter in the mud. The presence of Chaoborus punctipennis (Say) was also negatively correlated with maximum temperature of the mud and oxygen in the water during the summer (Hilsenhoff and Narf, 1968).

Fish predation has been shown to limit benthic populations (Aggus, 1971; Heuschele, 1969; Mrachek and Bachmann, 1967; Smith, 1969; Thomas, 1970). Dorris (1958) found fish predation to be an important factor in holding bottom fauna at a low level. Stomach analysis of bottom feeding fish in Tuttle Creek Reservoir showed aquatic insect larvae and numphs to be part of their diet (Klaassen and Marzolf, 1971).

Previous work on Red Rock Reservoir, after the first year of water impoundment, produced mean densities ranging from 3 to 35 organisms/m^2 at 9 stations during an 8-month study (Keith, 1971). Development of a macroinvertebrate community was described as extensive by Paterson and Fernando (1970) in two 6-month studies at 11 collecting sites in Laurel Creek Reservoir, Canada. They found monthly averages ranging from 1,078 organisms/m^2 to 17,896 organisms/m^2 after the first year of water impoundment and 3,135 organisms/m^2 to 20,162 organisms/m^2 after the second year. The benthic fauna was dominated by chironomids and oligochaetes with nematodes and oribatoid mites being subdominant. During the first two years of water impoundment, Nursall (1952) found total numbers ranging from 62 to 1,276 organisms/m^2 in monthly studies of Barrier Reservoir. The benthic fauna was composed of Chironomidae, Oligochaeta and *Gammarus*. Chironomid successions, as well as high numbers, were related to the age of reservoirs in studies by Aggus (1971) and Paterson and Fernando (1970).

Biomass measurements have been used to determine benthic productivity in lakes and reservoirs. In Clear Lake, Iowa and Lake Washington, the standing crop was considered to be average for comparable North American lakes (Mrachek and Bachmann, 1967; Thut, 1969). Oligochaete and chironomid dry weights were used to survey their distribution and abundance (Brinkhurst, 1970; Nursall, 1952). Hayne and Ball (1956) found benthic production to be 17 times the standing crop under fish predation.

The life cycle phenomena of benthic organisms can influence their distribution and abundance in several ways. Heuschele (1969) reported fluctuations in total benthic numbers due to the emergence patterns of Chironomidae and *Chaoborus punctipennis* (Say). Low numbers of *Chaoborus*, found in July and early August, were in part related to the timing of their life cycle (Bardach et al., 1951; Schmulbach and Sandholm, 1962). Early instars of _Chaoborus_ larvae were described by LaRow (1970) and Stahl (1966) as planktonic; whereas later instars were benthic diurnally and planktonic nocturnally. Wood (1956) suggested that migration of _Chaoborus_ larvae was adlittoral during the spring and early summer and ablittoral in the fall and early winter.

This study was conducted to determine the distribution of benthic invertebrates in Red Rock Reservoir after three years of water impoundment. By establishing stations across the reservoir on two different transects, subsequent sampling can provide information about reservoir benthic colonization and productivity. Determinations of the physiochemical characteristics of the substrate and bottom meter of water, along with water retention time, will provide a basis for determining relationships to benthic composition and distribution.

METHODS AND MATERIALS

Description of study area. Lake Red Rock, a mainstream reservoir created by Red Rock Dam, is located on the Des Moines River in central Iowa. It is 11.3 miles in length with a water surface elevation of 725 feet above sea level and conservation pool of 8,950 acres (3623.48 hectares). Water impoundment, for the purpose of flood control and low flow augmentation, began in March, 1969, under the supervision of the U. S. Army Corps of Engineers.

Two transects were established across the lake with six sampling stations along each transect. Transect A was situated near the lower end of the reservoir while Transect B was located above Whitebreast Bay near Elk Rock. Stations A-3 and B-4 were located in the old river channel. The other stations were located at increasing distances from the channel (Figure 1). A Lowrance Fish-Lo-Kator, Model No. LEP-300, was used in locating the old river channel.

Collection of sediments and bottom fauna. Weekly samples were taken between 10:00 AM and 3:00 PM CDST at each station for an 8-week period beginning June 9, 1972. A Ponar dredge was used to take duplicate samples at each station. Initial washing of the sediments was done using a wash bucket (Wildco) with a #30 mesh wire cloth bottom. The concentrated sediments were then returned to the laboratory. To facilitate the sorting process, approximately 10 ml of rose bengal solution was added to each sample (Thut, 1969). The samples were refrigerated until the next day when the final washing was completed with a U. S. Standard Series No. 50 sieve. The benthic fauna were hand-separated in white porcelain trays to major groups, counted and stored in 70% ethanol. Results were expressed as numbers of organisms/m^2. Further identification was done

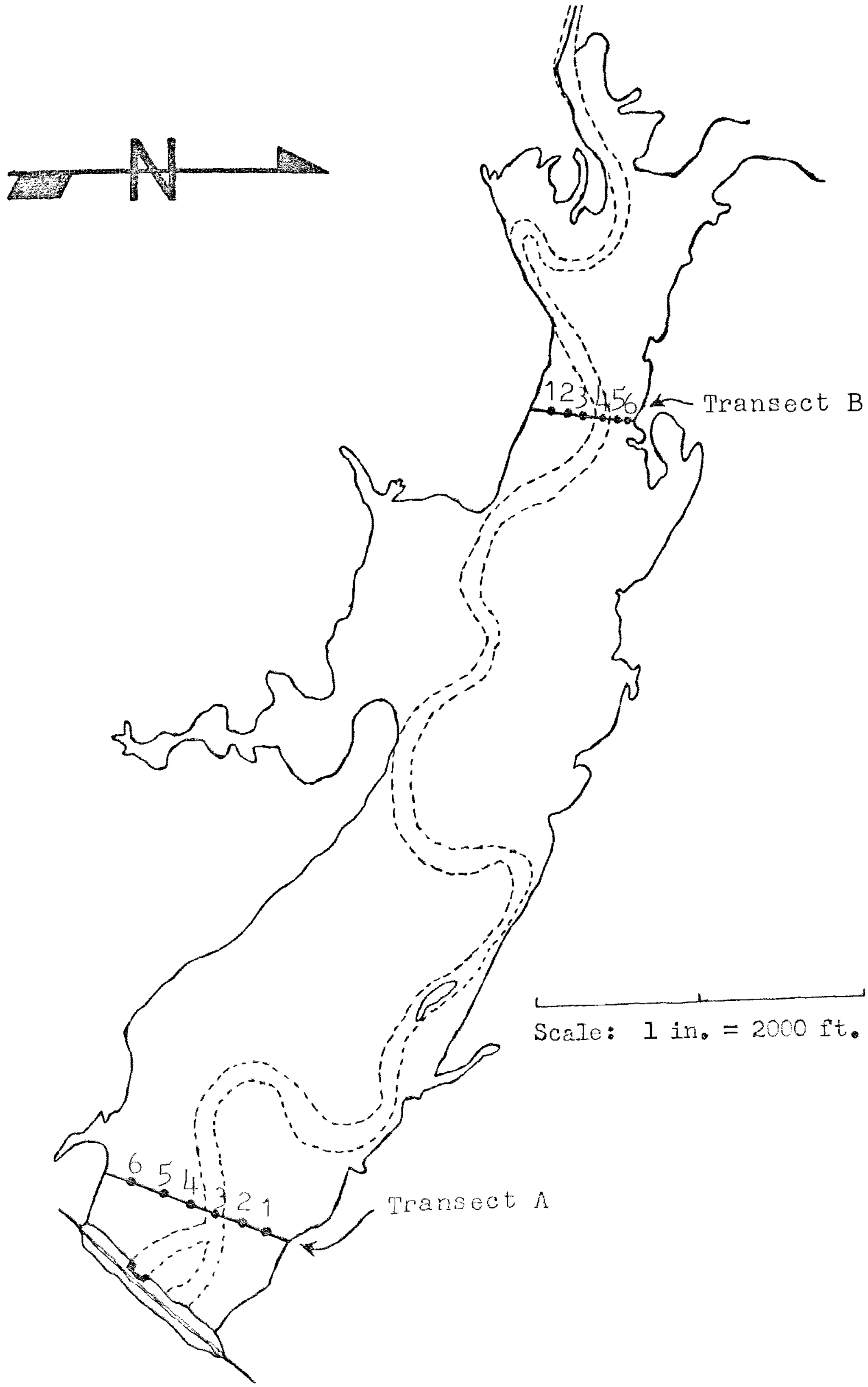

Figure 1. Location of transects and sampling stations during benthological study at Red Rock Reservoir, Iowa, Summer, 1972. Dotted lines outline the old river channel.

using Brinkhurst and Jamieson (1971), Edmondson (1959), Hauber (1947), Johannsen (1934a, b), Mason (1968), Nikolsky (1963), and Pennak (1953).

Prior to receiving the Ponar dredge, the Peterson dredge was used June 13 on Transect B. On July 25, comparisons were made at station B-6 between the Ponar and Peterson dredges. Two samples were taken with each dredge and results expressed as number/m^2. To determine the efficiency and consistency of the Ponar dredge and dredging procedure, a series of six samples were taken at station B-6 on July 18. A statistical analysis was made using the results, expressed as numbers per dredge sample.

Sediment analysis. Representative, non-sieved mud samples were dried to a constant weight and a sub-sample was ignited in an electric muffle furnace for 15 minutes at 600°C. After mixing the sample, it was burned for an additional 15 minutes and cooled in a desiccator for 30 minutes (APHA, 1971; Clampitt et al., 1960). Using a Mettler balance, the sample was re-weighed and percent volatile solids calculated from the loss on ignition. The remaining sub-samples were analyzed for pH values with a La Motte-Morgan soil testing set.

On July 5, samples from all stations were obtained for particle size analysis. After weighing, the dried samples were sifted through a U. S. Standard Sieve Series

(Welch, 1948). Each size category was weighed and percentages reported.

Water analysis. Water for chemical analysis was collected within one meter of the mud-water interface with a Kemmerer water bottle. The azide modification of the Winkler method was used for the determination of dissolved oxygen (APHA, 1971). Analysis of total alkalinity and free carbon dioxide was made in the field (Welch, 1948).

Water depth and temperature at the bottom was measured with a Yellow Springs electrical resistance telethermometer. Daily water levels and outflow rates, obtained from the records of the U. S. Army Corps of Engineers, Knoxville, Iowa, were used to determine water retention time during the study period (Clark, 1972).

Biomass determination. During the study, 10 representative oligochaetes and 10 Chironomidae were selected randomly for determination of biomass. Wet weights, to the nearest 0.1 mg, were determined for each group. The organisms were dried to a constant weight in a desiccator at room temperature (25°C), and re-weighed (Welch, 1948; McLachlan, 1970). The wet and dry weights of the larvae and worms, including the gut contents, were used to calculate biomass estimations.

RESULTS

Physical conditions. During the sampling period, bottom water temperatures ranged from a low of 16.0°C on August 1 to a high of 26.0°C on July 28 at Transect A. At Transect B the temperature ranged from a low of 18.5°C on July 11 to a high of 26.3°C on July 25. Lower temperatures and depletion of oxygen indicate the presence of thermal stratification in the old river channel at Transect B on June 30 and at Transect A on July 5 and 14 (Appendix A).

Depths at the stations on Transect A varied from 4.0 meters to 10.5 meters. On Transect B the depths varied from 1.2 meters to 4.5 meters. The greatest depths were measured at stations A-3 and B-4 which were located in the old river channel (Appendix A).

The calculated retention time for the water in the reservoir varied from a low of 3.9 days from June 17 to 22 to a high of 55.6 days from June 10 to 13. The values ranged from 10.8 to 14.7 days through the study period from June 28 to July 18 and from July 19 to August 1 values ranged from 4.0 to 6.1 days (Table 1). The retention times were generally very low throughout the study period averaging 11.7 days.

Chemical conditions. Values for dissolved oxygen on Transect A ranged from a high of 9.0 mg/l at station A-4 to a low of 0.7 mg/l at station A-3; whereas the values on

Table 1. The average hourly discharge rate (cfs) and the average retention time (days) of the water contained within the conservation pool during summer of 1972 (Clark, 1972).

Date	Average Discharge	Retention Time
June 5-9	6,800.0	6.7
June 10-13	816.7	55.6
June 14-16	10,305.4	4.4
June 17-22	11,666.7	3.9
June 23-27	5,601.4	8.1
June 28-30	3,904.2	11.6
July 1-5	3,227.0	14.1
July 6-11	3,255.0	13.9
July 12-14	3,088.9	14.7
July 15-18	4,201.6	10.8
July 19-21	11,234.0	4.0
July 22-25	7,751.6	5.9
July 26-28	9,938.9	4.6
July 29-Aug. 1	7,479.4	6.1

Transect B ranged from a high of 13.1 mg/l at station B-2 to a low of 3.1 mg/l at station B-4 (Appendix B). Variations of the dissolved oxygen concentration on Transect B were not appreciable except on June 30 when the lowest value was recorded in the old river channel. There were, however, appreciable differences in the values recorded from Transect A, particularly in the old river channel on June 16, July 5, 14 and 28 and on August 1. There was a general decrease in dissolved oxygen values during the study period, which could be related to decreased solubility as the temperature also generally increased.

The concentration of carbon dioxide ranged from a high of 33 mg/l at station A-3 to a low of 2 mg/l at station A-6. On Transect B the concentrations ranged from a high of 36 mg/l at station B-5 to a low of 0 mg/l (Appendix B). As the summer progressed the levels of carbon dioxide generally decreased.

Total alkalinity on Transect A ranged from a high of 233 mg/l at station A-3 to a low of 113 mg/l at station A-1. Values on Transect B ranged from a high of 264 mg/l at station B-2 to a low of 137 mg/l at station B-1 (Appendix B). Carbonate values were recorded on July 18 from Transect B. Bicarbonate values at Transect B were slightly higher than those at Transect A.

Substrate conditions. The pH of the substrate on Transect A ranged from a low of 6.6 to a high of 7.1. On Transect B the pH ranged from a low of 6.6 to a high of 7.2 (Appendix A). Throughout the study period the values remained relatively uniform.

On Transect A the organic content of the mud varied from 5.2 to 18.6 percent and from 4.2 to 13.2 percent on Transect B (Appendix A). When volatile solids were averaged for the study period, station A-6 exhibited the highest percentage where large amounts of organic debris were observed at the sampling site and station A-4 exhibited the lowest percentage. Station B-6 had the lowest mean percentage on Transect B with a higher amount of fine sand observed while collecting samples. Transect A showed greatest fluctuation in mean values between stations, while Transect B was more uniform for all stations (Table 2). The percentage of volatile solids was relatively consistent throughout the study period for each station.

Observations made during the dredging procedure indicated a fine layer of brown silt on the top of the substrate. Generally beneath this was a thicker, dark black layer, characterized by the odor of hydrogen sulfide.

Particle size analysis of the substratum showed a high concentration of coarse, medium and fine sand. Most of the remaining amount of substrate was composed of very fine sand, silt and clay. The substratum did not contain

Table 2. Sediment analysis at Red Rock Reservoir. Particulate analysis was done with sediments collected at each station on July 5, 1972. Cobbles, pebbles, granules and very coarse sand (> 1.19 mm); coarse, medium and fine sand (1.19-.149 mm); very fine sand, silt and clay (< .149). Mean ($\bar{x}$) percent volatile solids was calculated from the values for each station during the study period. Each size category and mean volatile solids is given in percentages.

Station	Cobbles, pebbles, granules & very coarse sand	Coarse, medium, & fine sand	Fine sand, silt & clay	$\bar{x}$ Volatile solids
A-1	.5	68.5	31.0	11.5
A-2	3.2	64.7	32.1	10.2
A-3	3.2	74.3	22.5	11.9
A-4	5.5	76.0	18.5	6.9
A-5	1.7	56.1	42.2	10.2
A-6	0.0	69.8	30.2	13.3
B-1	.5	60.9	38.6	9.6
B-2	7.3	70.0	22.7	10.1
B-3	.6	75.0	24.4	10.6
B-4	1.9	78.7	19.4	11.3
B-5	1.5	69.8	28.7	9.8
B-6	.5	57.9	41.6	8.2

an appreciable amount of cobbles, pebbles, or granules (Table 2). Station A-4 exhibited the highest concentration of sand which coincided with a low mean percent volatile solids.

Benthos populations. Three major groups of organisms composed most of the populations sampled and identified: Oligochaeta, Chironomidae and *Chaoborus punctipennis* (Say). Those found occasionally during the study, referred to as "Others" in this paper, included Odonata, Nematoda, and Cyprinidae. Mean densities on Transect A ranged from 108 organisms/m^2 at station A-5 to 25 organisms/m^2 at station A-6. Transect B had mean densities ranging from 212 organisms/m^2 at station B-6 to 85 organisms/m^2 at station B-4 (Table 3).

The Oligochaeta were dominant organisms making up 52.4 percent of the total organisms collected. Oligochaetes showed a slight increase over the study period. Numerous cocoons of the Oligochaeta were observed in the washed samples. The Chironomidae comprised 44.8 percent of the total organisms collected. Chironomid numbers increased during the study period except for the last two sampling days. *Chaoborus punctipennis* (Say) made up 2.8 percent of the total populations collected and they were more prominent on the last two sampling days (Appendix C).

Biomass calculations were made from the data recorded

Table 3. Statistical analysis of numbers of benthic organisms collected at each station. Mean numbers are expressed as numbers/m^2. The mean ($\overline{X}$) for total numbers does not include the "Others" collected. Oligo.=Oligochaeta; Chir.=Chironomidae; Chao.= *Chaoborus punctipennis* (Say)

Station	$\overline{X}$ Oligo.	$\overline{X}$ Chao.	$\overline{X}$ Chir.	$\overline{X}$ Total Numbers	$\pm$	$S_{\overline{X}}$
A-1	33	6	51	90	$\pm$	52
A-2	24	2	43	69	$\pm$	43
A-3	46	12	26	84	$\pm$	52
A-4	53	4	46	103	$\pm$	30
A-5	26	0	82	108	$\pm$	45
A-6	12	0	12	25	$\pm$	4
B-1	78	0	41	120	$\pm$	25
B-2	109	0	28	137	$\pm$	30
B-3	90	1	34	125	$\pm$	72
B-4	46	0	39	85	$\pm$	52
B-5	88	4	69	160	$\pm$	94
B-6	80	8	124	212	$\pm$	120

Table 4. Benthic biomass (dry and wet weights) values using numbers of organisms collected on the first day (June 16-Transect A, June 13-Transect B) and the last day (August 1) of the study period. Biomass Δ = change in biomass during study period.

	$\bar{x}$ wt. (mg)	June 13 & 16 g/hectare	Aug. 1 g/hectare	Biomass Δ g/hectare
<u>Dry</u> <u>Weights</u>				
Transect A				
Oligochaeta	.00106	.384	.666	.282
Chironomidae	.00032	.005	.223	.218
Transect B				
Oligochaeta	.00106	.230	1.689	1.459
Chironomidae	.00032	.006	.166	.160
<u>Wet</u> <u>Weights</u>				
Transect A				
Oligochaeta	.00313	1.221	1.972	.751
Chironomidae	.00198	.034	1.380	1.346
Transect B				
Oligochaeta	.00313	.679	4.986	4.305
Chironomidae	.00198	.040	1.030	.990

on the first and last sampling days. On Transect A the oligochaetes exhibited the least amount of increase in wet and dry biomass, while the chironomids showed very high increases in biomass during the two months. Transect B produced a higher increase in oligochaete biomass than Transect A, while the chironomids also showed similar increases in biomass (Table 4).

Six replicate samples were taken with the Ponar dredge at station B-6, resulting in 18, 19, 27, 16, 26 and 21 organisms per dredge sample. With a mean value of 21.17 organisms per sample, the standard error of the mean was 1.82.

Results of the duplicate sampling with the Peterson and Ponar dredges at station B-6 produced 237 and 255 organisms/m^2, respectively. To provide a means of converting the values, obtained with the Peterson dredge at Transect B, to comparable Ponar values, the June 13 values were multiplied times 1.0759. These converted values were recorded in Appendix C.

DISCUSSION

The potentially rich nature of the environment of Red Rock Reservoir would suggest that a benthic community would colonize the habitat in large numbers. Little development of the macroinvertebrate community at Red Rock Reservoir is evident, after three years of water impoundment, with mean densities ranging from 24 to 212 organisms/m^2 (Table 3). Keith (1971) found mean densities ranging from 3 to 35 organisms/m^2 after the first year of water impoundment. Although these results indicate a higher level of development over three years, it is not nearly as extensive compared to other new reservoirs (Nursall, 1952; Paterson and Fernando, 1970; Thomas, 1970). At Laurel Creek Reservoir monthly averages ranged from 3,135 to 20,162 organisms/m^2 after the second year of water impoundment (Paterson and Fernando, 1970) and at Barrier Reservoir mean densities ranged from 62 to 1,276 organisms/m^2 during the first two years of water impoundment (Nursall, 1952).

Three major groups of organisms found during this study were Oligochaeta, Chironomidae and *Chaoborus punctipennis* (Say) (Appendix C). Previous study (Keith, 1971) on Red Rock Reservoir showed similar benthic community composition. Except for *Chaoborus* larvae, similar community composition was found in new reservoirs (Nursall, 1952; Paterson and Fernando, 1970).

The oligochaete population composed 52.4% of the total number of organisms collected compared to 8.8% (Keith, 1971) in a previous study (Appendix C). It appears that the oligochaetes have colonized much of the reservoir bottom since impoundment began and are responding with higher productivity to the more favorable substrate. The oligochaete populations showed some preference for the more shallow area on Transect B compared to Transect A; however, their numbers appear to have been influenced more by the organic content of the mud.

In the present study the chironomid population composed 44.8% of the total number of organisms collected compared to 2.6% (Keith, 1971) in an earlier study (Appendix C). It appears that several species of chironomids have established themselves since impoundment began. Aggus (1971), Nursall (1952), and Paterson and Fernando (1970) related changes in the bottom sediments to a pattern of chironomid succession in newly established reservoirs. The general decrease in chironomid numbers at the end of July may be related to lower amounts of dissolved oxygen present; however, it is more likely that emergence of the larvae had begun. The gradual increase in temperature midway through the study period corresponds to an increase in chironomids (Appendix A and C). Heuschele (1969) reported temperature accelerates emergence patterns of dipteran larvae which seems applicable to this study. Paterson and Fernando (1970) found a rapid sequential pattern of colonization of Chironomidae resulting from warm water temperatures. Although chironomid densities have been shown to increase with depth (Cowell and Hudson, 1967), it does not seem that depth was a major regulatory factor of chironomid populations in Red Rock Reservoir.

The _Chaoborus_ larvae composed 2.8% of the total population collected, with an increase in numbers evident at the end of July (Appendix C). The low numbers of _Chaoborus_ larvae collected in the present study may give evidence of the life cycle pattern of the larvae at Red Rock. It could be that the major part of the _Chaoborus_ population had emerged prior to the first collection in June. Keith (1971), in an 8-month study, found _Chaoborus_ larvae to compose 88.6% of the organisms collected, but verified low numbers from June through August at Red Rock Reservoir. Heuschele (1969) found _Chaoborus punctipennis_ (Say) emerged in late May and produced eggs, which later emerged in July and August. Studies of Lewis and Clark Reservoir and West Lake Okoboji verify low _Chaoborus_ numbers during the summer months (Bardach et al., 1951; Schmulbach and Sandholm, 1962). Studies by LaRow (1970) and Stahl (1966) found early instars of _Chaoborus_ to be planktonic at all times, which would have allowed them to escape the dredge in this study. They also found later instars to be benthic diurnally and planktonic nocturnally, possibly coinciding with a rise in numbers at the end of the present study.

Of the population of _Chaoborus_ larvae collected, most of them were collected at the deeper portion of the reservoir on Transect A (Figure 2). Craven and Brown (1969), Hilsenhoff and Narf (1968), Juday (1921) and Johnson and Matheson (1968) verified this relationship between depth and distribution of Chaoborus larvae. It seems likely, in this study, that the Chaoborus larvae can tolerate the lower oxygen concentration, particularly at Transect A, as their numbers began to increase near the end of the study period. The presence of Chaoborus larvae in the summer was negatively correlated with oxygen concentration in the water (Hilsenhoff and Narf, 1968).

The substrate appears to have played an important role in controlling benthic abundance and distribution in Red Rock Reservoir. Compared to other stations, station A-6 had large amounts of bulky debris, resulting in higher percentages of volatile solids, which was inversely related to the number of organisms collected. Those stations having a mean organic content of 6 to 10% produced larger numbers of organisms, possibly due to individual species preference. Clampitt et al. (1960) support this as they found most of the benthic fauna at stations having 5-10% organic content. Several genera of Chironomidae accounted for this population, while oligochaetes were found at all stations, particularly those with higher organic content. Hilsenhoff and Narf (1968) negatively correlated numbers of several species of Chironomidae with the organic content of the mud. This correlation seems to be applicable to station B-6, as it showed a lower mean percent of volatile solids and large amounts of fine sand (Table 2), with a corresponding higher number of chironomids compared to other stations (Figure 2).

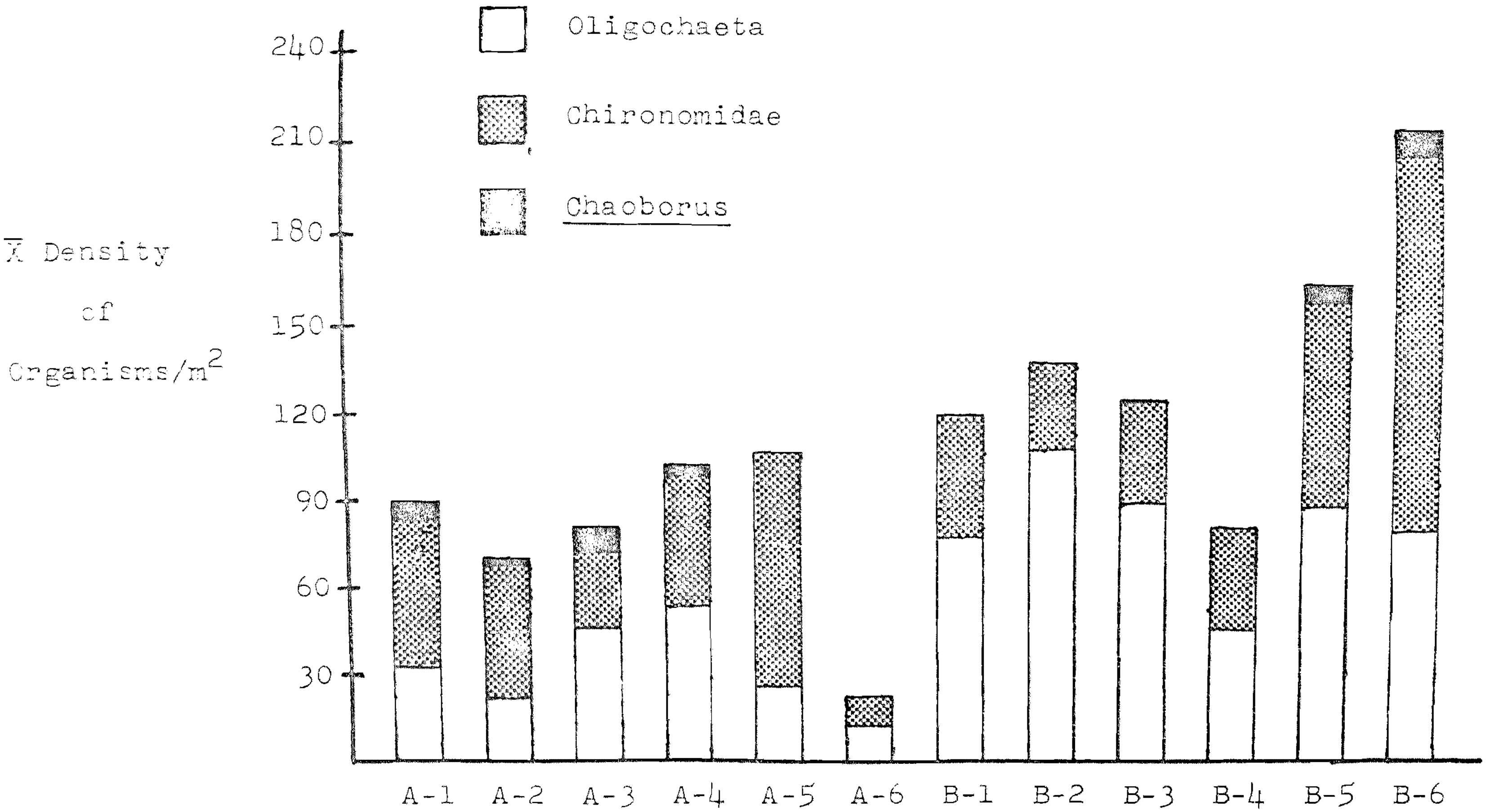

Figure 2. Mean density of benthic organisms/m^2 collected at each sampling station during the summer, 1972, in Red Rock Reservoir.

It is possible that there is a point where the amount of sand and other inorganic material is limiting (Cowell and Hudson, 1967) and may account for the lower numbers at Red Rock.

Differences in mean numbers of benthic fauna between Transect A and B were evident with higher numbers associated with Transect B (Figure 2). The oligochaetes accounted for much of this difference. Thomas (1970) and Grimas (1961) found the bottom-associated organisms to decrease in number from the headend to the downstream end of a reservoir due to progressive deposition of nutrient material. Johnson and Matheson (1968) and Brinkhurst (1970) reported high oligochaete populations in the vicinity of inflows into lakes. Such deposition of nutrient material may explain higher numbers found at Transect B in Red Rock; however, this nutrient deposition is not evident in increased percent volatile solids (Table 2). It is possible that increasing years of water impoundment may amplify nutrient deposition.

Water retention times were low, averaging 11.7 days, during the study period (Table 1). Low retention time could explain reduced numbers of benthic fauna in Red Rock Reservoir as they may be carried out of the reservoir, while migrating or becoming established in the mud. Keith (1971) related low retention time in Red Rock to low numbers of benthic organisms. Cowell and Hudson (1967) found high water discharge rates produced a significant loss of benthic fauna, which was earlier suggested by Schmulbach and Sandholm (1962). Paterson and Fernando (1970) reported an average retention time of 63 days and, as discussed earlier, very high benthic populations.

Other physical and chemical characteristics of the mud and water did not seem to have an appreciable effect on the benthic populations. The dissolved carbon dioxide and total alkalinity values of the bottom water and the mud pH values were relatively uniform throughout the study period. This uniformity can be attributed to low retention time and consequent circulation within the reservoir (Nursall, 1952) and may indirectly affect benthic populations by influencing their food sources.

Investigations into possible horizontal differences of benthic faunal populations across the reservoir bottom were made from the data of the last collecting day, August 1, comparing the two old river channel stations to the other 10 non-channel stations. Figure 2 shows the mean numbers in the old river channel stations (A-3 and B-4) to be generally lower than the other non-channel stations. Differences between the old river channel stations and non-channel stations were highly significant with a t test on total numbers of organisms collected. These differences may be due to lower values of dissolved oxygen in the old river channel, depth relationships and/or a more favorable substrate at other stations. McLachlan (1970) suggested the invasion of a new habitat was affected by oviposition, supplemented by migration of the larval population.

Although there was a definite increase in benthic biomass over the 8-week study period, the standing crop of benthic fauna at Red Rock was quite low. The combined oligochaete and chironomid dry weights ranged from .899 g/ha at Transect A to 1.855 g/ha at Transect B on August 1 (Table 4). Nursall (1952) found standing crops of bottom fauna in Barrier Reservoir to range from 1,940 to 18,820 g/ha dry weight over a two year study period. This was considered to be small compared to other lakes and reservoirs in the Rocky Mountains. Thut (1969) considered benthic dry weight in Lake Washington to be average compared to other North American lakes, producing a value of 8,030 g/ha. Similar comparison to lakes in Iowa (Mrachek and Bachmann, 1967) found Clear Lake at an intermediate level, producing an average wet weight of 8,630 g/ha.

It seems possible that while the standing crop is low, the rate of production is high in Red Rock. During the 8-week study, the oligochaete dry weight increased by factors of 1.7 to 7.3 times at Transects A and B, while the chironomid dry weight increased by factors of 44.6 to 27.7 times at Transects A and B (Table 4). Hayne and Ball (1956) found average production of bottom fauna during a growing season to be 17 times the standing crop when fish were present. Emergent patterns were not included in the production estimates of this study and the total effect of fish predation on production was unknown. Since there is a population of buffalo fish and carp in Red Rock, fish predation may be an important factor reducing benthic standing crop. Dorris (1958) found predation, particularly by carp, was important in effecting low numbers of bottom fauna. Channel catfish were also found to ingest aquatic insect larvae and numphs (Klaassen and Marzolf, 1971).

After three years of water impoundment, it can be expected that the substrate would be modified by siltation and decomposition (Nursall, 1952; Paterson and Fernando, 1970; Thomas, 1970). In a corresponding area of Red Rock on Transect A, Keith (1971) found the bottom sediments to have a mean volatile solids content of 6.6% during a previous study compared to a mean of 10.7% in the present study. The corresponding area of Transect B in 1970 had a mean of 7.5% compared to 9.9% in this study (Table 2). Paterson and Fernando (1970) found an average of 31.5% volatile solids during the first year of water impoundment, while Clampitt et al. (1960) found, in Millers Bay, Lake Okoboji, volatile solids composed 5 to 31% of the total weight of the sediments. These figures suggest that the percent volatile solids of Red Rock Reservoir is below the average of other reservoirs and lakes.

The statistical analysis of the replicate sampling with the Ponar dredge produced a mean value of 21.17 organisms and the standard error of the mean equal to 1.82. The coefficient of variation was rather high, being 21%. Hudson (1970) and Flannagan (1970) found the Ponar dredge to be most versatile in sampling a variety of sediments. By lowering the dredge slowly, utilizing the screen covered top, it was expected, that the pressure build-up and associated disturbance over the superficial sediments, would be minimized (Hamilton, 1971).

The most obvious need for further study of benthic populations involves a thorough identification of the several taxonomic groups found in Red Rock Reservoir. The Chironomidae and Oligochaeta populations must be delineated to genus and species and the benthophagic specimens of the Cyprindae deserve further attention. Yearly studies are necessary to determine life cycle patterns of the several species present. Opportunity for a careful secondary productivity study exists, including an estimation of the loss of benthic organisms through the concrete conduits of the dam and fish predation in the reservoir. Investigation into the amount of sedimentation that occurs in the reservoir, as it influences benthic abundance, needs development.

SUMMARY

Benthic samples were taken weekly on two transects in Red Rock Reservoir, using a Ponar dredge, during the summer of 1972. Physiochemical conditions of the substrate and bottom water were determined and related to benthic abundance and distribution.

Three major groups of organisms were collected during the study period: Chironomidae, Oligochaeta and *Chaoborus punctipennis* (Say). Oligochaeta composed 52.4%, the Chironomidae 44.8% and the *Chaoborus* larvae 2.8% of the total organisms collected.

The mean numbers of organisms for each station was comparably low, ranging from 24 organisms/m^2 at station A-6 to 212/m^2 at station B-6.

The following conclusions were drawn from this study:

1. Benthic standing crop of Red Rock Reservoir during the summer, 1972, expressed in terms of biomass and mean numbers, was below average for a mainstream reservoir after three years of water impoundment.
2. The rate of benthic productivity appears to be reasonably high in Red Rock.
3. Low numbers of *Chaoborus* larvae found during this study may be closely related to the life cycle patterns of the larvae.

4. The organic content and particle size of the substrate seemed to be important factors in controlling benthic distribution.
5. Low water retention time appears to decrease benthic abundance.
6. The percent volatile solids of the sediments of Red Rock appear to be below average for lakes and reservoirs.
7. Differences between the old river channel stations and the other non-channel stations were highly significant with a t test on total numbers of organisms collected.
8. Recommendations for further study include:
   a. Specific identification of the several taxonomic groups found in Red Rock, including the Chironomidae, Oligochaeta and Cyprinidae.
   b. Yearly studies to determine life cycle patterns of the dipteran larvae.
   c. Benthic production studies including fish predation and population losses through outflow.
   d. Investigation into the amount of sedimentation and subsequent influence on benthic abundance.

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APPENDICES

Appendix A. The depth, bottom water temperature, mud pH and % volatile solids at each station in Red Rock Reservoir, 1972.

Station Date	Depth (m)	Temp. (°C)	Mud pH	% Volatile Solids
A-1				
6-16	6.5	22.4	7.0	10.5
6-22	5.5	19.5	6.8	9.3
6-27	5.0	17.0	6.9	11.5
7-5	6.0	21.2	6.9	13.5
7-14	5.3	24.0	7.0	11.9
7-21	5.8	24.8	6.9	12.2
7-28	5.3	25.0	6.9	11.9
8-1	6.5	16.0	-	-
A-2				
6-16	7.0	21.7	6.9	11.8
6-22	6.0	20.0	7.0	13.0
6-27	5.0	17.0	7.0	10.6
7-5	5.5	21.5	6.8	9.2
7-14	5.0	25.0	6.9	7.6
7-21	5.5	24.5	6.9	10.7
7-28	5.0	26.0	6.9	8.5
8-1	5.5	16.0	-	-
A-3				
6-16	10.5	21.5	7.0	10.9
6-22	10.0	20.0	6.8	13.1
6-27	9.0	17.5	6.9	9.6
7-5	10.0	18.5	6.9	13.3
7-14	10.0	21.5	7.0	12.4
7-21	10.3	24.0	7.0	10.6
7-28	10.0	25.0	6.8	13.1
8-1	9.5	16.0	-	-
A-4				
6-16	6.0	20.7	7.0	8.6
6-22	5.0	20.0	6.6	5.8
6-27	5.5	18.5	6.9	7.4
7-5	5.0	21.8	6.7	5.4
7-14	4.8	25.0	7.0	5.2
7-21	6.0	25.0	6.9	8.6
7-28	4.0	26.0	6.8	7.5
8-1	4.5	17.0	-	-

Appendix A. Continued.

Station Date	Depth (m)	Temp. (°C)	Mud pH	% Volatile Solids
A-5				
6-16	6.5	22.0	7.2	11.1
6-22	6.0	19.7	7.0	11.7
6-27	4.5	18.5	7.0	10.6
7-5	6.0	21.5	6.8	8.8
7-14	6.0	24.0	6.9	9.2
7-21	6.0	24.5	6.8	11.6
7-28	5.5	26.0	7.0	8.3
8-1	6.5	19.0	-	-
A-6				
6-16	6.0	22.0	-	-
6-22	7.0	20.0	7.0	13.4
6-27	6.0	18.5	6.9	11.3
7-5	6.5	21.2	6.8	18.6
7-14	6.5	24.0	7.1	12.4
7-21	6.5	24.5	6.8	12.4
7-28	6.5	26.0	6.9	11.7
8-1	7.0	19.5	-	-
B-1				
6-13	1.5	23.5	7.0	9.8
6-22	1.5	21.0	7.1	11.2
6-30	1.5	23.0	7.1	8.2
7-5	2.0	22.0	7.0	8.6
7-11	1.5	18.5	7.0	9.5
7-18	1.5	23.8	6.9	8.7
7-25	1.8	26.0	7.0	11.0
8-1	1.5	24.5	-	-
B-2				
6-13	1.3	23.5	7.0	9.6
6-22	2.0	21.0	6.9	9.5
6-30	2.0	23.5	7.1	10.5
7-5	1.5	19.5	6.8	8.5
7-11	1.8	20.0	7.0	11.4
7-18	1.3	23.8	6.8	10.6
7-25	1.8	26.3	6.9	10.7
8-1	1.5	24.3	-	-

Appendix A. Continued.

Station Date	Depth (m)	Temp. (°C)	Mud pH	% Volatile Solids
B-3				
6-13	2.0	23.5	7.0	10.7
6-22	3.0	20.0	7.1	12.6
6-30	2.5	23.5	7.0	9.8
7-5	2.0	20.5	7.2	10.5
7-11	2.0	21.8	7.2	11.6
7-18	1.5	23.5	6.8	10.3
7-25	2.0	26.0	7.0	8.4
8-1	1.5	24.3	-	-
B-4				
6-13	4.5	23.5	7.2	8.1
6-22	4.0	20.0	7.2	13.2
6-30	4.0	20.5	7.1	10.8
7-5	4.0	20.3	6.9	11.5
7-11	4.5	20.8	7.2	11.1
7-18	4.3	23.8	6.8	11.3
7-25	4.5	22.5	7.2	12.8
8-1	4.2	24.0	-	-
B-5				
6-13	1.8	23.5	7.0	11.2
6-22	1.5	21.0	7.0	9.9
6-30	1.5	23.2	7.0	8.4
7-5	2.0	19.0	7.0	10.6
7-11	1.5	24.5	7.0	10.2
7-18	1.3	23.8	6.7	9.8
7-25	1.5	25.5	6.9	8.6
8-1	2.0	24.0	-	-
B-6				
6-13	1.5	23.8	7.0	10.2
6-22	1.5	20.0	6.6	6.2
6-30	1.2	23.5	6.9	4.2
7-5	1.5	20.8	7.0	9.4
7-11	1.5	24.5	6.9	9.7
7-18	1.3	23.3	6.7	9.6
7-25	1.5	25.5	6.8	8.3
8-1	1.5	24.0	-	-

Appendix B. Chemical analysis of bottom meter of water at each station including dissolved oxygen, percent oxygen saturation, total alkalinity and dissolved carbon dioxide. All values are given in mg/l except percent oxygen saturation. Total alkalinity was equal to bicarbonate values, except those noted with an asterisk (*), which also included carbonate values. (Red Rock Reservoir, 1972)

Station Date	D.O.	% O_2 Sat.	Alkal.	CO_2
A-1				
6-16	7.2	82	205	16
6-22	7.9	85	205	24
6-27	3.2	32	153	27
7-5	5.8	64	189	18
7-14	6.5	75	113	12
7-21	4.0	48	197	7
7-28	5.4	64	204	6
8-1	1.4	14	192	7
A-2				
6-16	6.5	74	208	12
6-22	7.2	78	209	23
6-27	5.2	53	211	24
7-5	7.2	80	206	18
7-14	7.6	90	175	10
7-21	3.3	38	195	5
7-28	5.0	60	200	4
8-1	2.5	26	200	5
A-3				
6-16	2.7	30	217	17
6-22	6.5	70	209	24
6-27	4.1	42	220	24
7-5	1.1	11	233	31
7-14	.7	8	204	33
7-21	3.2	37	182	6
7-28	3.2	37	215	9
8-1	1.8	18	199	7

Appendix B. Continued.

Station Date	D.O.	% O_2 Sat.	Alkal.	CO_2
A-4				
6-16	4.8	53	206	28
6-22	7.7	83	208	24
6-27	6.3	66	224	21
7-5	7.6	85	210	16
7-14	9.0	105	191	6
7-21	4.7	55	195	5
7-28	6.8	82	205	4
8-1	6.5	65	206	5
A-5				
6-16	6.8	76	221	26
6-22	6.3	68	207	23
6-27	7.2	75	224	18
7-5	6.5	72	202	16
7-14	6.5	75	198	9
7-21	5.0	58	192	4
7-28	6.8	82	200	4
8-1	5.8	62	210	5
A-6				
6-16	7.4	83	222	24
6-22	7.7	83	209	23
6-27	6.3	66	231	19
7-5	6.5	72	208	18
7-14	4.3	50	199	10
7-21	4.7	55	191	2
7-28	6.1	74	155	5
8-1	3.2	35	209	6
B-1				
6-13	8.7	100	234	19
6-22	8.8	97	240	23
6-30	10.4	120	176	0
7-5	6.8	76	174	17
7-11	9.0	95	174	11
7-18	6.5	75	159	0
7-25	6.8	82	137	4
8-1	7.9	93	263	0

Appendix B. Continued.

Station Date	D.O.	% O_2 Sat.	Alkal.	CO_2
B-2				
6-13	6.2	72	233	31
6-22	8.8	97	238	24
6-30	13.1	142	187	0
7-5	7.6	80	172	17
7-11	8.6	94	193	5
7-18	6.8	88	206*	0
7-25	6.1	75	140	3
8-1	7.9	93	264	0
B-3				
6-13	7.3	84	231	32
6-22	8.7	95	238	25
6-30	10.3	120	187	7
7-5	6.8	75	174	14
7-11	6.5	72	193	10
7-18	6.8	78	208*	0
7-25	5.8	70	227	5
8-1	-	-	-	-
B-4				
6-13	7.5	85	231	22
6-22	8.8	95	240	24
6-30	3.1	34	220	12
7-5	7.2	79	171	18
7-11	6.5	74	191	11
7-18	6.3	74	208	0
7-25	6.1	69	244	6
8-1	6.5	76	260	2
B-5				
6-13	7.1	83	229	36
6-22	8.8	97	235	23
6-30	11.2	130	200	5
7-5	6.5	68	181	19
7-11	9.0	105	189	7
7-18	6.5	75	219*	0
7-25	6.1	73	233	5
8-1	-	-	-	-

Appendix B. Continued.

Station Date	D.O.	% O_2 Sat.	Alkal.	CO_2
B-6				
6-13	8.4	97	229	27
6-22	8.5	93	224	22
6-30	9.9	115	208	7
7-5	6.1	68	184	20
7-11	7.5	87	188	10
7-18	7.6	88	208*	0
7-25	5.8	70	225	6
8-1	-	-	-	-

Appendix C. Density of benthic fauna collected at each station (number/m^2) at Red Rock Reservoir, 1972. "Others" represents Nematoda, Odonata and Cyprinidae collected which are not included in the mean values.

Station / Taxonomic group	6/16	6/22	6/27	7/5	7/14	7/21	7/28	8/1	mean values
A-1									
Oligochaeta	132	28	0	10	19	10	28	38	33
Chaoborus	0	0	0	19	0	0	0	28	6
Chironomidae	10	0	19	57	67	47	132	76	51
Others	0	0	0	0	0	0	0	0	
A-2									
Oligochaeta	19	28	10	10	10	10	57	47	24
Chaoborus	0	0	0	0	0	0	0	19	2
Chironomidae	0	10	19	28	10	66	113	95	43
Others	0	0	0	0	0	0	0	0	
A-3									
Oligochaeta	28	76	57	10	28	10	47	113	46
Chaoborus	0	0	0	19	0	0	38	38	12
Chironomidae	0	28	10	10	10	47	10	95	26
Others	0	0	0	0	0	0	0	0	
A-4									
Oligochaeta	19	0	28	170	19	38	19	132	53
Chaoborus	0	0	0	0	10	19	0	0	4
Chironomidae	0	10	10	19	38	161	76	57	46
Others	0	0	0	10	0	0	10	0	
A-5									
Oligochaeta	19	0	0	38	57	57	10	28	26
Chaoborus	0	0	0	0	0	0	0	0	0
Chironomidae	0	10	10	66	28	340	104	95	82
Others	0	0	0	0	0	0	0	0	
A-6									
Oligochaeta	-	0	0	10	10	28	19	19	12
Chaoborus	-	0	0	0	0	0	0	0	0
Chironomidae	-	28	10	10	28	10	0	0	12
Others	-	0	0	0	47	0	0	0	

Appendix C. Continued.

Station Taxonomic group	6/13	6/22	6/30	7/5	7/11	7/18	7/25	8/1	mean values
B-1									
Oligochaeta	11	95	47	47	38	104	104	180	78
Chaoborus	0	0	0	0	0	0	0	0	0
Chironomidae	0	0	0	57	95	66	66	47	41
Others	0	0	19	0	0	0	0	0	
B-2									
Oligochaeta	32	132	28	76	47	236	161	161	109
Chaoborus	0	0	0	0	0	0	0	0	0
Chironomidae	0	0	10	28	66	47	47	28	28
Others	0	0	0	0	10	0	0	0	
B-3									
Oligochaeta	22	95	76	66	57	236	66	104	90
Chaoborus	0	0	0	0	0	0	10	0	1
Chironomidae	11	10	10	57	85	47	19	28	34
Others	0	10	0	10	19	0	0	0	
B-4									
Oligochaeta	11	38	28	47	28	95	19	104	46
Chaoborus	0	0	0	0	0	0	0	0	0
Chironomidae	0	10	28	28	47	142	28	28	39
Others	0	10	0	10	0	0	0	19	
B-5									
Oligochaeta	32	85	38	76	28	142	142	161	88
Chaoborus	0	0	0	0	0	10	0	19	4
Chironomidae	0	10	38	28	104	180	66	123	69
Others	0	0	0	0	19	0	0	0	
B-6									
Oligochaeta	22	10	0	76	47	151	85	246	80
Chaoborus	0	0	0	28	0	10	28	0	8
Chironomidae	0	113	199	151	123	208	142	57	124
Others	0	0	0	0	0	0	0	0	